FIG.1

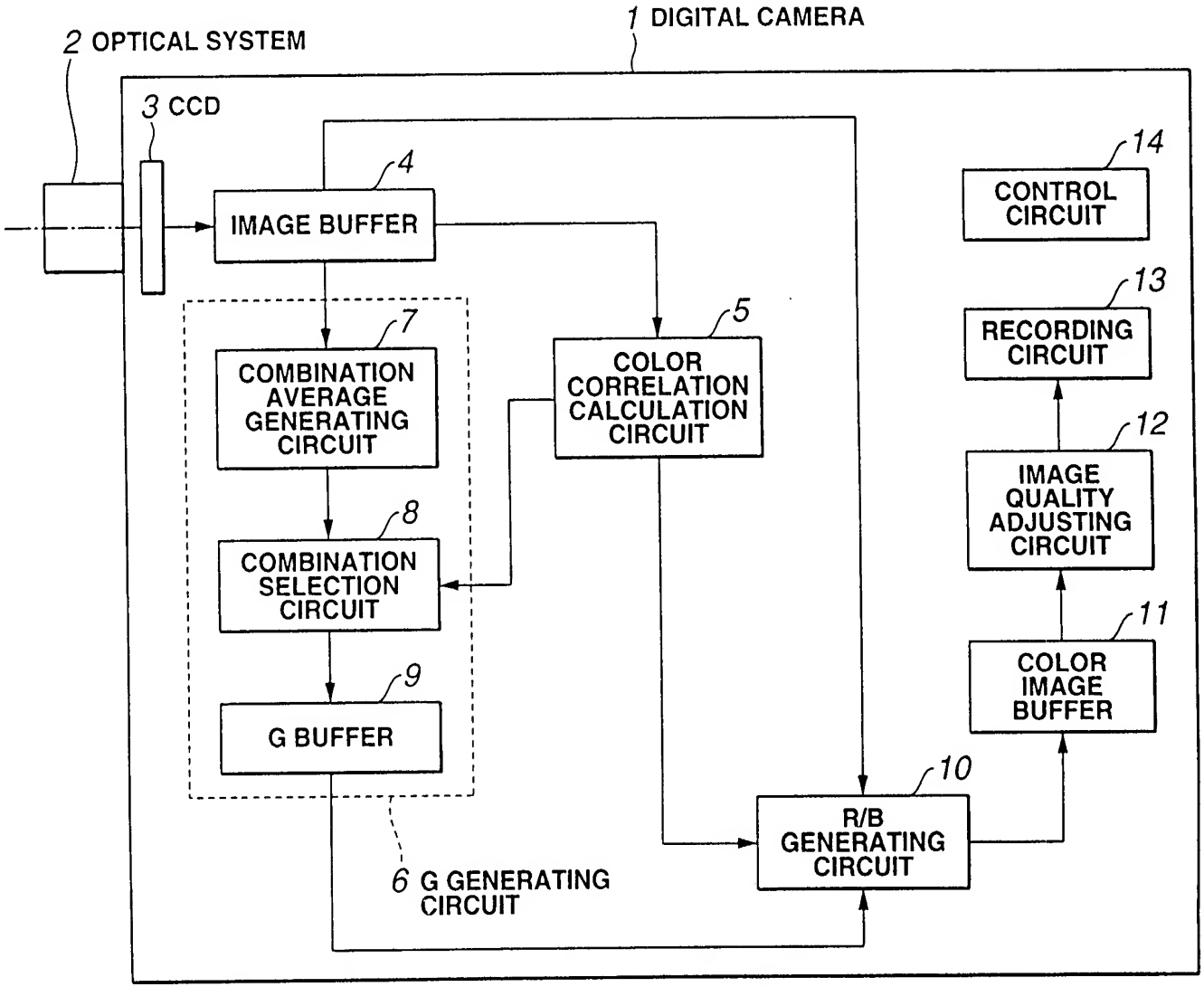
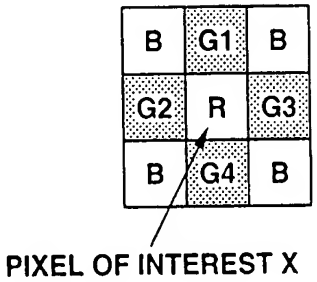

1 DIGITAL CAMERA
2 OPTICAL SYSTEM
3 CCD
4
IMAGE BUFFER
5
COLOR CORRELATION CALCULATION CIRCUIT
6 G GENERATING CIRCUIT
7
COMBINATION AVERAGE GENERATING CIRCUIT
8
COMBINATION SELECTION CIRCUIT
9
G BUFFER
10
R/B GENERATING CIRCUIT
11
COLOR IMAGE BUFFER
12
IMAGE QUALITY ADJUSTING CIRCUIT
13
RECORDING CIRCUIT
14
CONTROL CIRCUIT

FIG.2A



$$V1 = \frac{G1 + G4}{2}, \quad d1 = |G1 - G4|$$

$$V2 = \frac{G2 + G3}{2}, \quad d2 = |G2 - G3|$$

$$V3 = \frac{G1 + G2}{2},$$

$$V4 = \frac{G3 + G4}{2},$$

$$V5 = \frac{G1 + G3}{2},$$

$$V6 = \frac{G2 + G4}{2},$$

FIG.2B

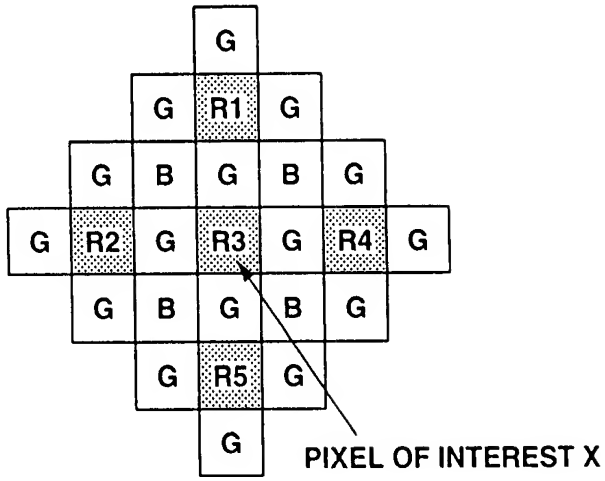


FIG.3

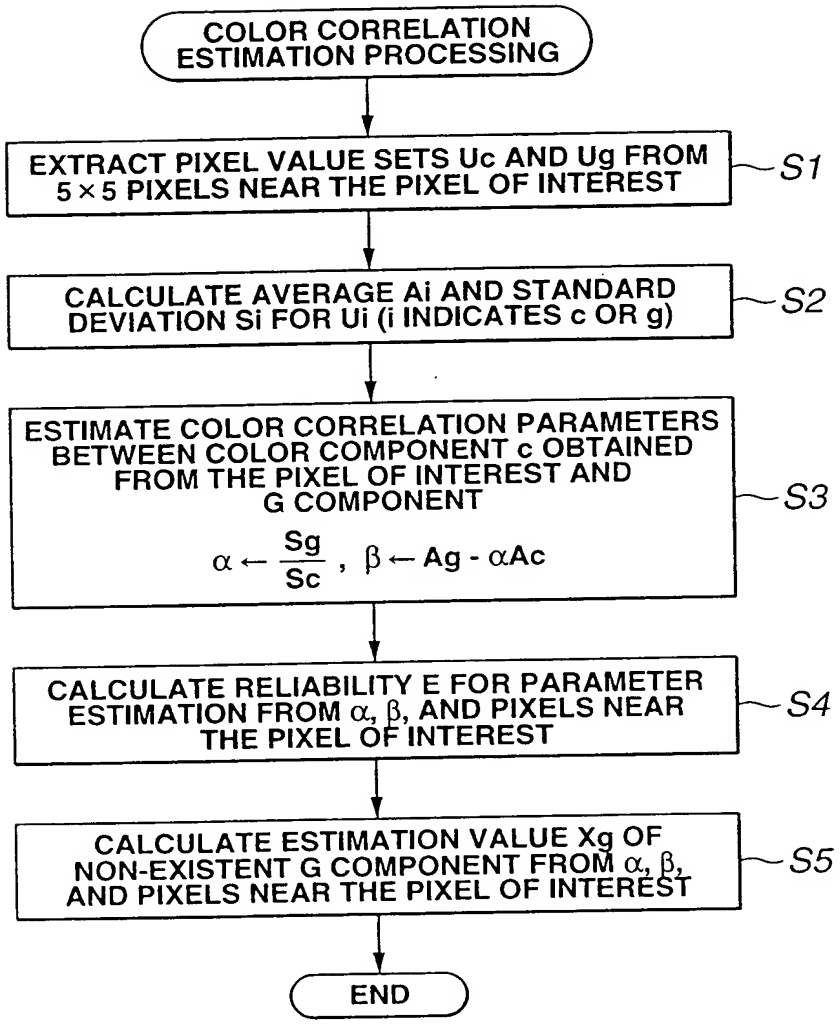

COLOR CORRELATION ESTIMATION PROCESSING
EXTRACT PIXEL VALUE SETS Uc AND Ug FROM 5×5 PIXELS NEAR THE PIXEL OF INTEREST
S1
CALCULATE AVERAGE Ai AND STANDARD DEVIATION Si FOR Ui (i INDICATES c OR g)
S2
ESTIMATE COLOR CORRELATION PARAMETERS BETWEEN COLOR COMPONENT c OBTAINED FROM THE PIXEL OF INTEREST AND G COMPONENT
$\alpha \leftarrow \frac{Sg}{Sc}$, $\beta \leftarrow Ag - \alpha Ac$
S3
CALCULATE RELIABILITY E FOR PARAMETER ESTIMATION FROM α, β, AND PIXELS NEAR THE PIXEL OF INTEREST
S4
CALCULATE ESTIMATION VALUE Xg OF NON-EXISTENT G COMPONENT FROM α, β, AND PIXELS NEAR THE PIXEL OF INTEREST
S5
END

FIG.4

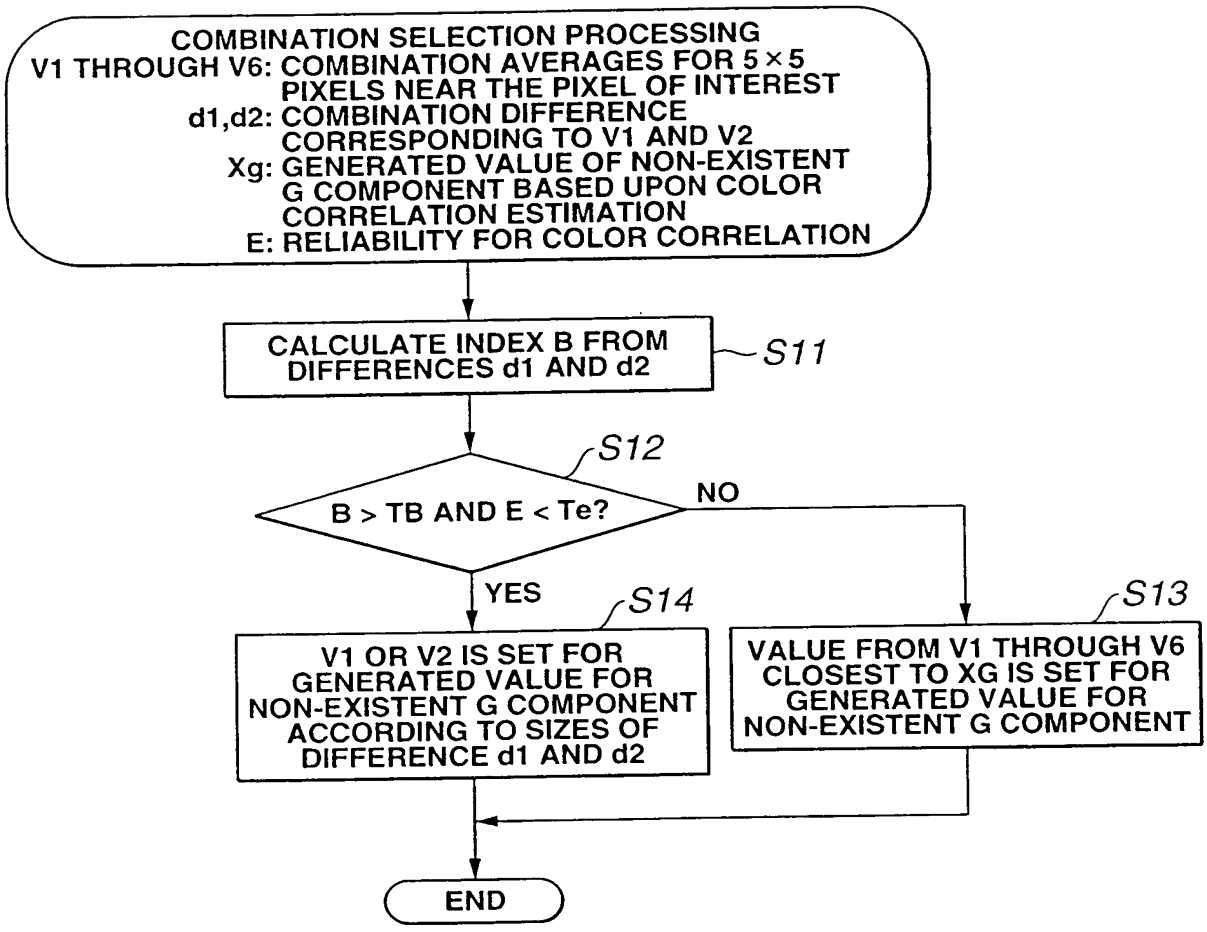

COMBINATION SELECTION PROCESSING
V1 THROUGH V6: COMBINATION AVERAGES FOR 5×5 PIXELS NEAR THE PIXEL OF INTEREST
d1,d2: COMBINATION DIFFERENCE CORRESPONDING TO V1 AND V2
Xg: GENERATED VALUE OF NON-EXISTENT G COMPONENT BASED UPON COLOR CORRELATION ESTIMATION
E: RELIABILITY FOR COLOR CORRELATION
CALCULATE INDEX B FROM DIFFERENCES d1 AND d2
S11
S12
B > TB AND E < Te?
NO
YES
S14
V1 OR V2 IS SET FOR GENERATED VALUE FOR NON-EXISTENT G COMPONENT ACCORDING TO SIZES OF DIFFERENCE d1 AND d2
S13
VALUE FROM V1 THROUGH V6 CLOSEST TO XG IS SET FOR GENERATED VALUE FOR NON-EXISTENT G COMPONENT
END

FIG.5A

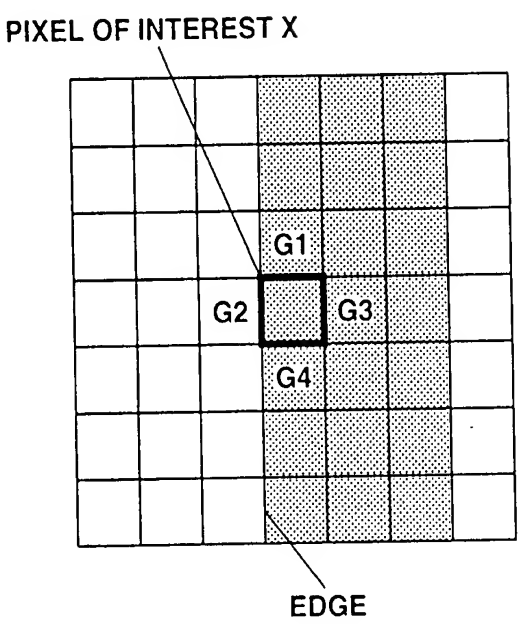

PIXEL OF INTEREST X
G1
G2
G3
G4
EDGE

FIG.5B

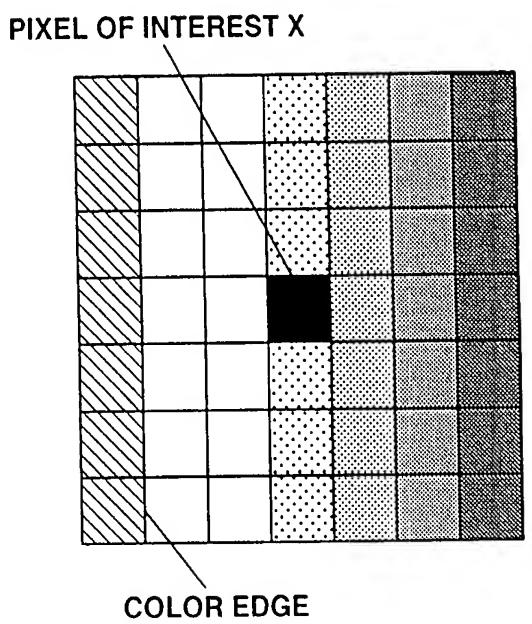

PIXEL OF INTEREST X
COLOR EDGE

FIG.6

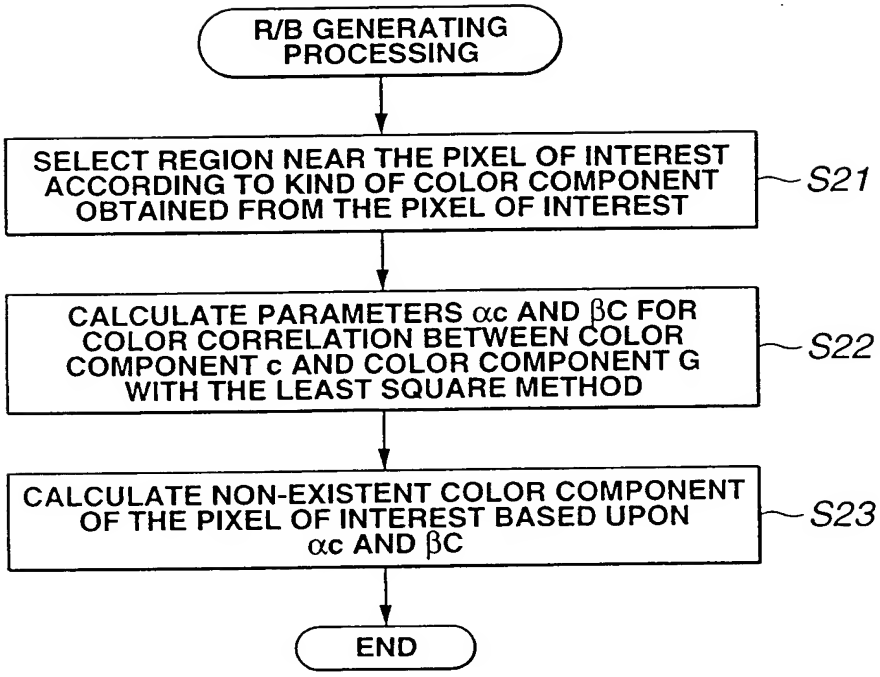
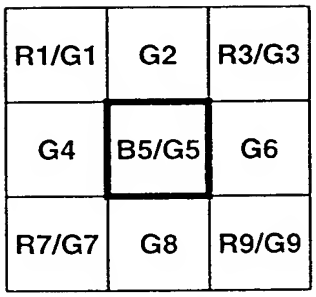
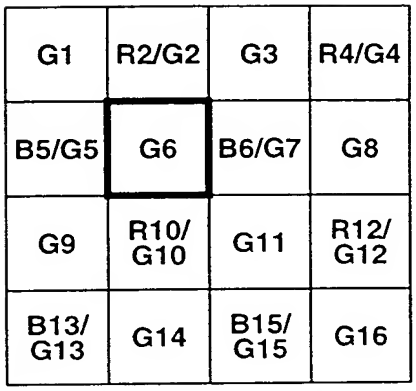

R/B GENERATING PROCESSING
SELECT REGION NEAR THE PIXEL OF INTEREST ACCORDING TO KIND OF COLOR COMPONENT OBTAINED FROM THE PIXEL OF INTEREST
S21
CALCULATE PARAMETERS αc AND βC FOR COLOR CORRELATION BETWEEN COLOR COMPONENT c AND COLOR COMPONENT G WITH THE LEAST SQUARE METHOD
S22
CALCULATE NON-EXISTENT COLOR COMPONENT OF THE PIXEL OF INTEREST BASED UPON αc AND βC
S23
END

FIG.7A



R-G: Y: G1 G3 G7 G9
Z: R1 R3 R7 R9

FIG.7B



R-G: Y: G2 G4 G10 G12
Z: R2 R4 R10 R12

B-G: Y: G5 G7 G13 G15
Z: B5 B7 B13 B15

FIG.8

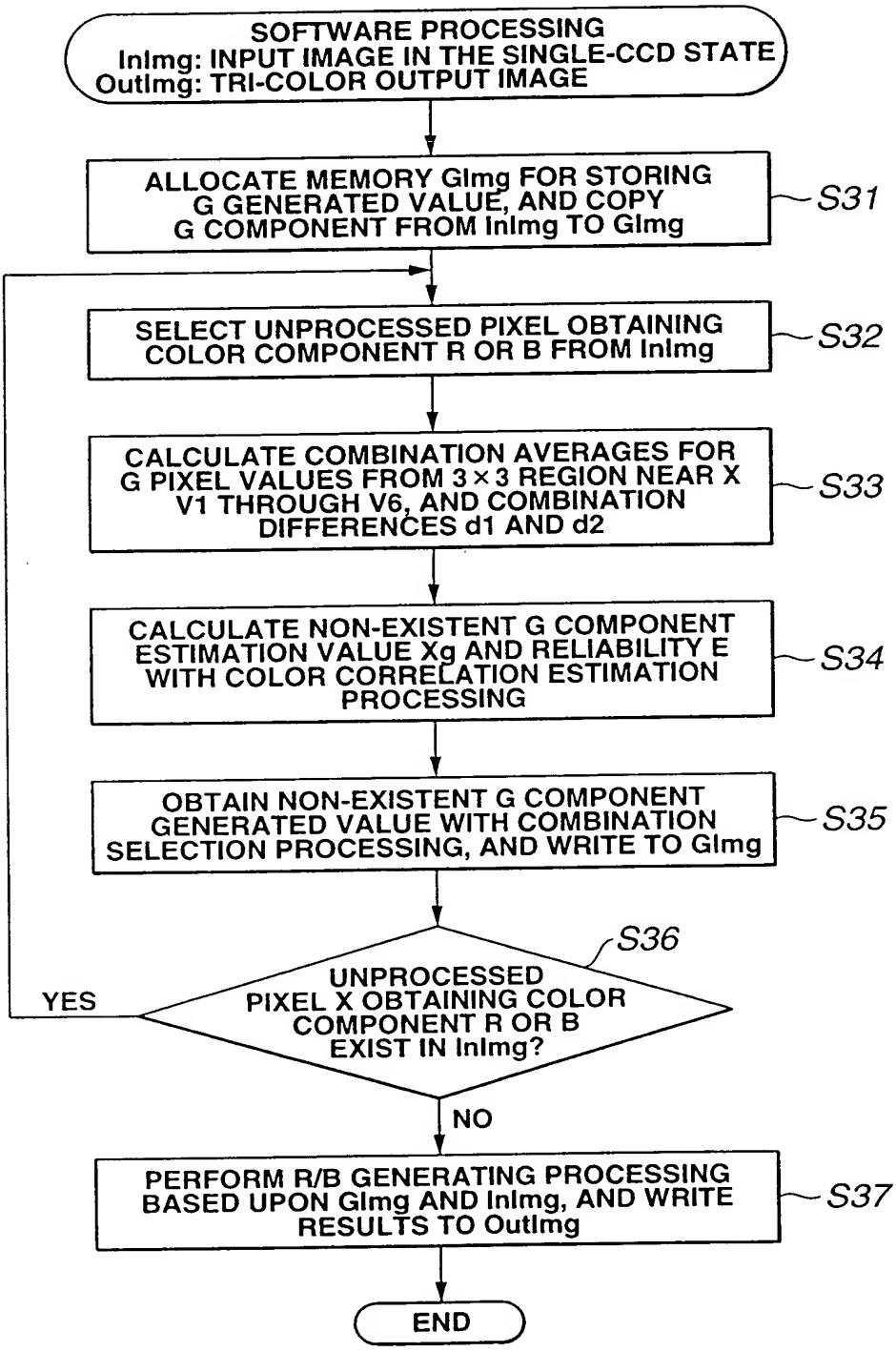

SOFTWARE PROCESSING
InImg: INPUT IMAGE IN THE SINGLE-CCD STATE
OutImg: TRI-COLOR OUTPUT IMAGE
ALLOCATE MEMORY GImg FOR STORING G GENERATED VALUE, AND COPY G COMPONENT FROM InImg TO GImg
S31
SELECT UNPROCESSED PIXEL OBTAINING COLOR COMPONENT R OR B FROM InImg
S32
CALCULATE COMBINATION AVERAGES FOR G PIXEL VALUES FROM 3×3 REGION NEAR X V1 THROUGH V6, AND COMBINATION DIFFERENCES d1 AND d2
S33
CALCULATE NON-EXISTENT G COMPONENT ESTIMATION VALUE Xg AND RELIABILITY E WITH COLOR CORRELATION ESTIMATION PROCESSING
S34
OBTAIN NON-EXISTENT G COMPONENT GENERATED VALUE WITH COMBINATION SELECTION PROCESSING, AND WRITE TO GImg
S35
S36
UNPROCESSED PIXEL X OBTAINING COLOR COMPONENT R OR B EXIST IN InImg?
YES
NO
PERFORM R/B GENERATING PROCESSING BASED UPON GImg AND InImg, AND WRITE RESULTS TO OutImg
S37
END

FIG.9

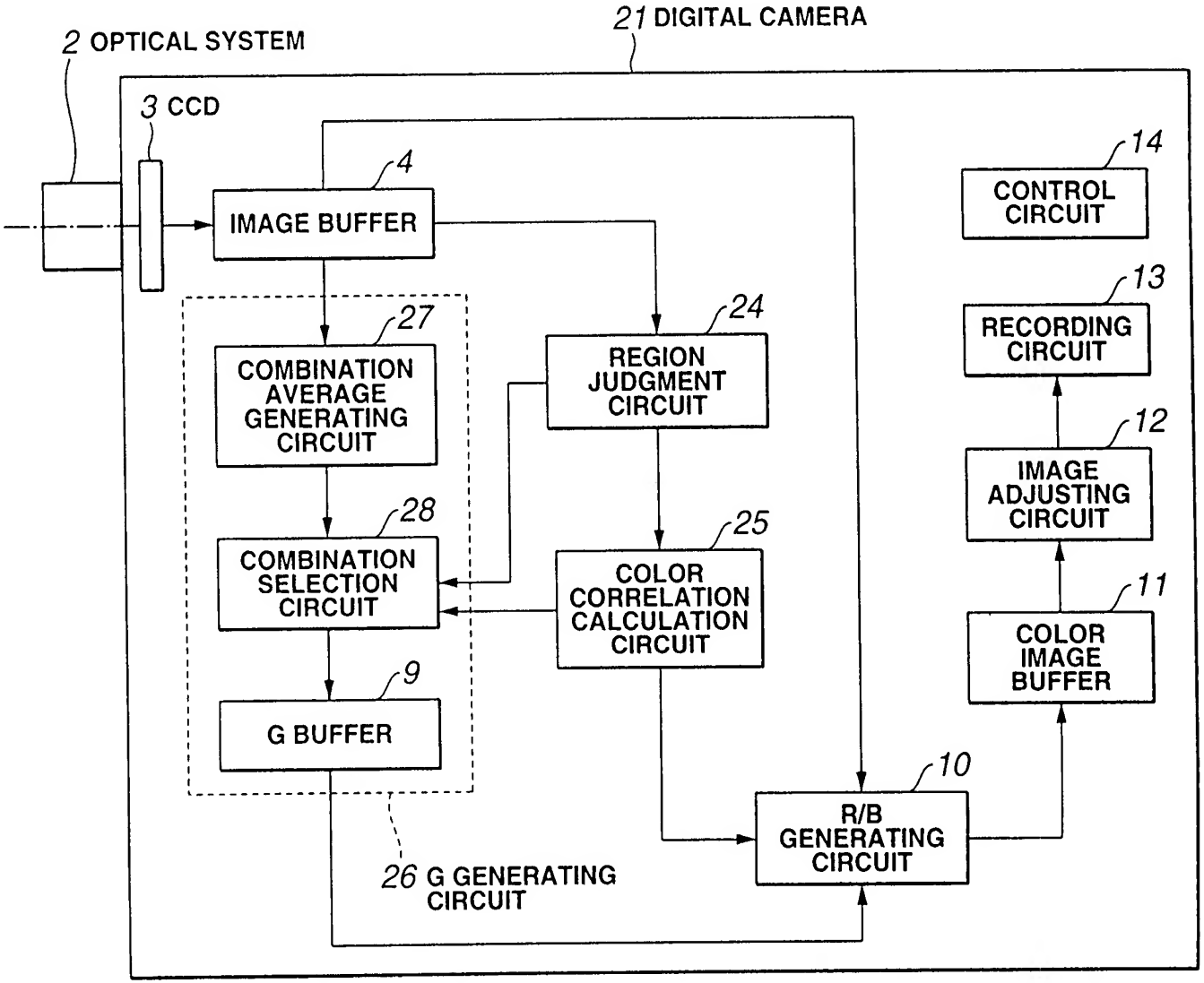
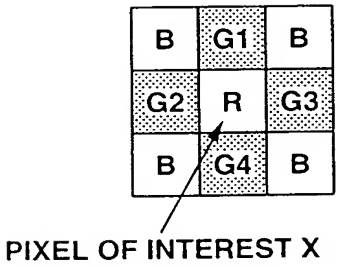

2 OPTICAL SYSTEM
21 DIGITAL CAMERA
3 CCD
4
IMAGE BUFFER
14
CONTROL CIRCUIT
13
RECORDING CIRCUIT
27
COMBINATION AVERAGE GENERATING CIRCUIT
24
REGION JUDGMENT CIRCUIT
12
IMAGE ADJUSTING CIRCUIT
28
COMBINATION SELECTION CIRCUIT
25
COLOR CORRELATION CALCULATION CIRCUIT
11
COLOR IMAGE BUFFER
9
G BUFFER
10
R/B GENERATING CIRCUIT
26 G GENERATING CIRCUIT

FIG.10



$$V1 = \frac{G1 + G4}{2}, \quad d1 = |G1 - G4|$$

$$V2 = \frac{G2 + G3}{2}, \quad d2 = |G2 - G3|$$

$$V3 = \frac{G1 + G2}{2}, \quad d3 = |G1 - G2|$$

$$V4 = \frac{G3 + G4}{2}, \quad d4 = |G3 - G4|$$

$$V5 = \frac{G1 + G3}{2}, \quad d5 = |G1 - G3|$$

$$V6 = \frac{G2 + G4}{2}, \quad d6 = |G2 - G4|$$

FIG.11A

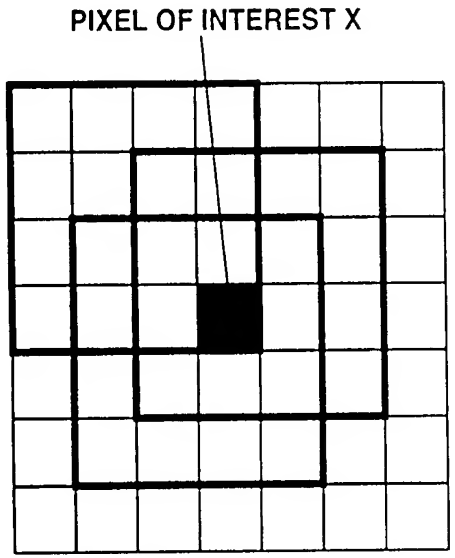


FIG.11B

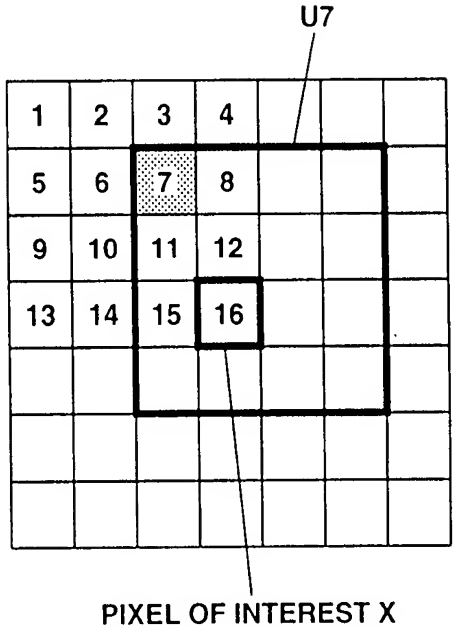


FIG.11C

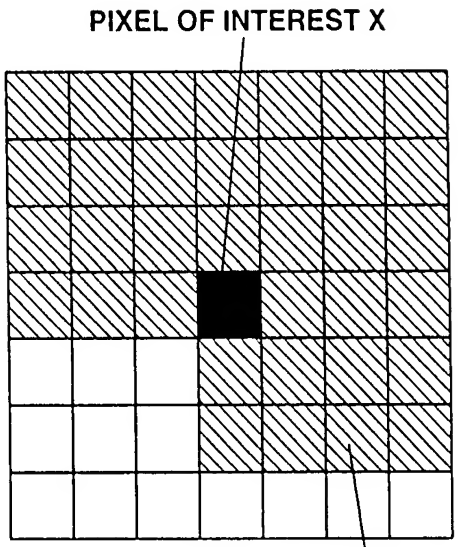


FIG.12

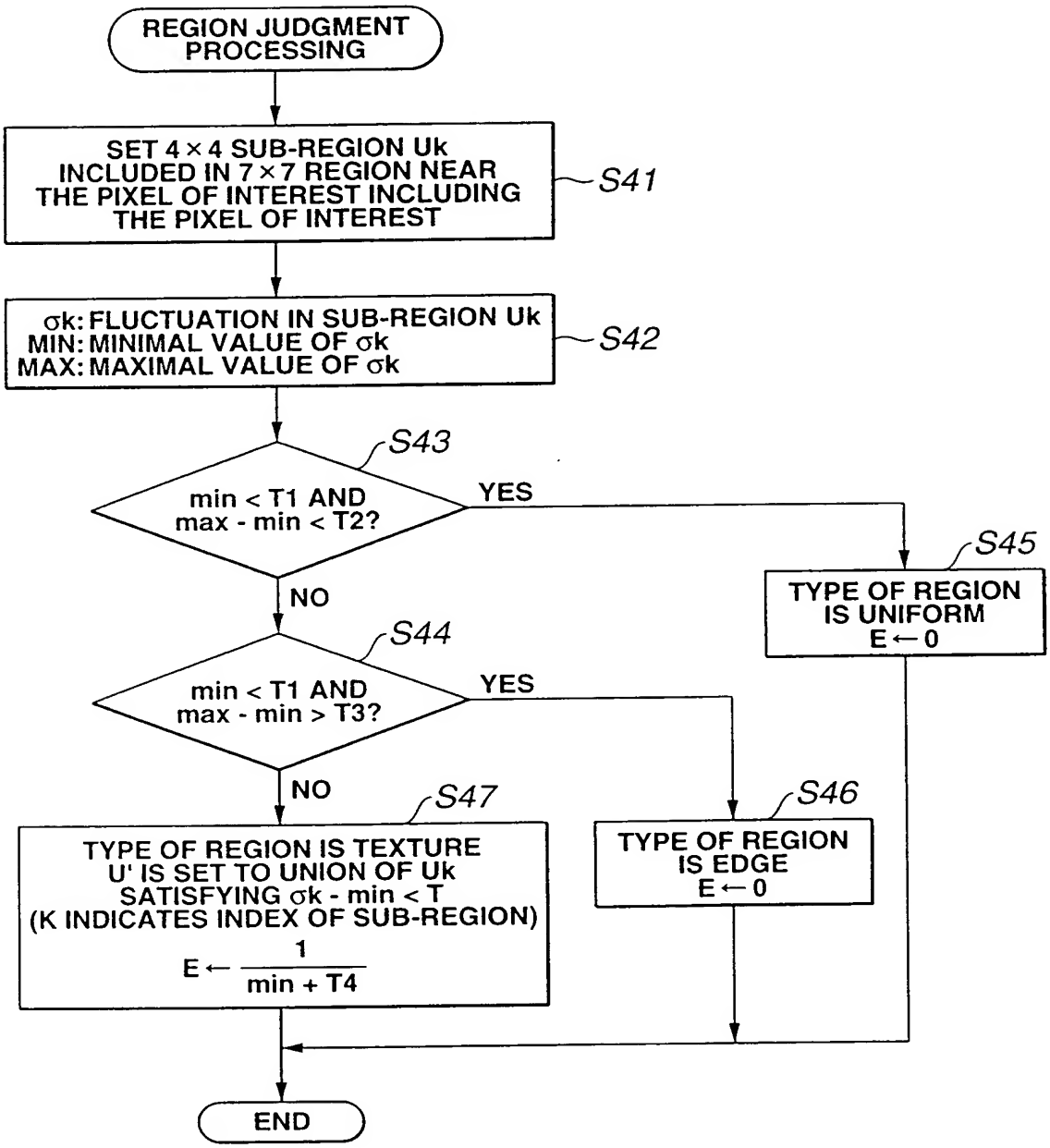

REGION JUDGMENT PROCESSING
SET 4×4 SUB-REGION Uk INCLUDED IN 7×7 REGION NEAR THE PIXEL OF INTEREST INCLUDING THE PIXEL OF INTEREST
S41
σk: FLUCTUATION IN SUB-REGION Uk
MIN: MINIMAL VALUE OF σk
MAX: MAXIMAL VALUE OF σk
S42
S43
min < T1 AND max - min < T2?
YES
NO
S45
TYPE OF REGION IS UNIFORM
E ← 0
S44
min < T1 AND max - min > T3?
YES
NO
S47
TYPE OF REGION IS TEXTURE
U' IS SET TO UNION OF Uk SATISFYING σk - min < T
(K INDICATES INDEX OF SUB-REGION)
E ← 1/(min + T4)
S46
TYPE OF REGION IS EDGE
E ← 0
END

FIG.13

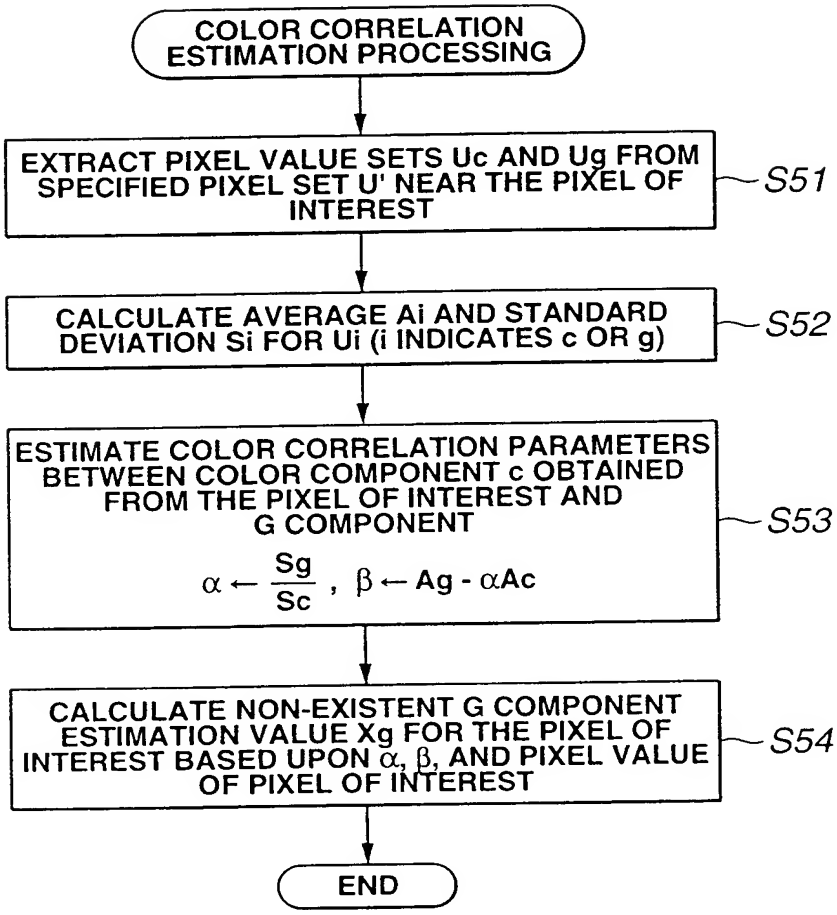

COLOR CORRELATION ESTIMATION PROCESSING
EXTRACT PIXEL VALUE SETS Uc AND Ug FROM SPECIFIED PIXEL SET U' NEAR THE PIXEL OF INTEREST
S51
CALCULATE AVERAGE Ai AND STANDARD DEVIATION Si FOR Ui (i INDICATES c OR g)
S52
ESTIMATE COLOR CORRELATION PARAMETERS BETWEEN COLOR COMPONENT c OBTAINED FROM THE PIXEL OF INTEREST AND G COMPONENT
$\alpha \leftarrow \frac{Sg}{Sc}$, $\beta \leftarrow Ag - \alpha Ac$
S53
CALCULATE NON-EXISTENT G COMPONENT ESTIMATION VALUE Xg FOR THE PIXEL OF INTEREST BASED UPON α, β, AND PIXEL VALUE OF PIXEL OF INTEREST
S54
END

FIG.14

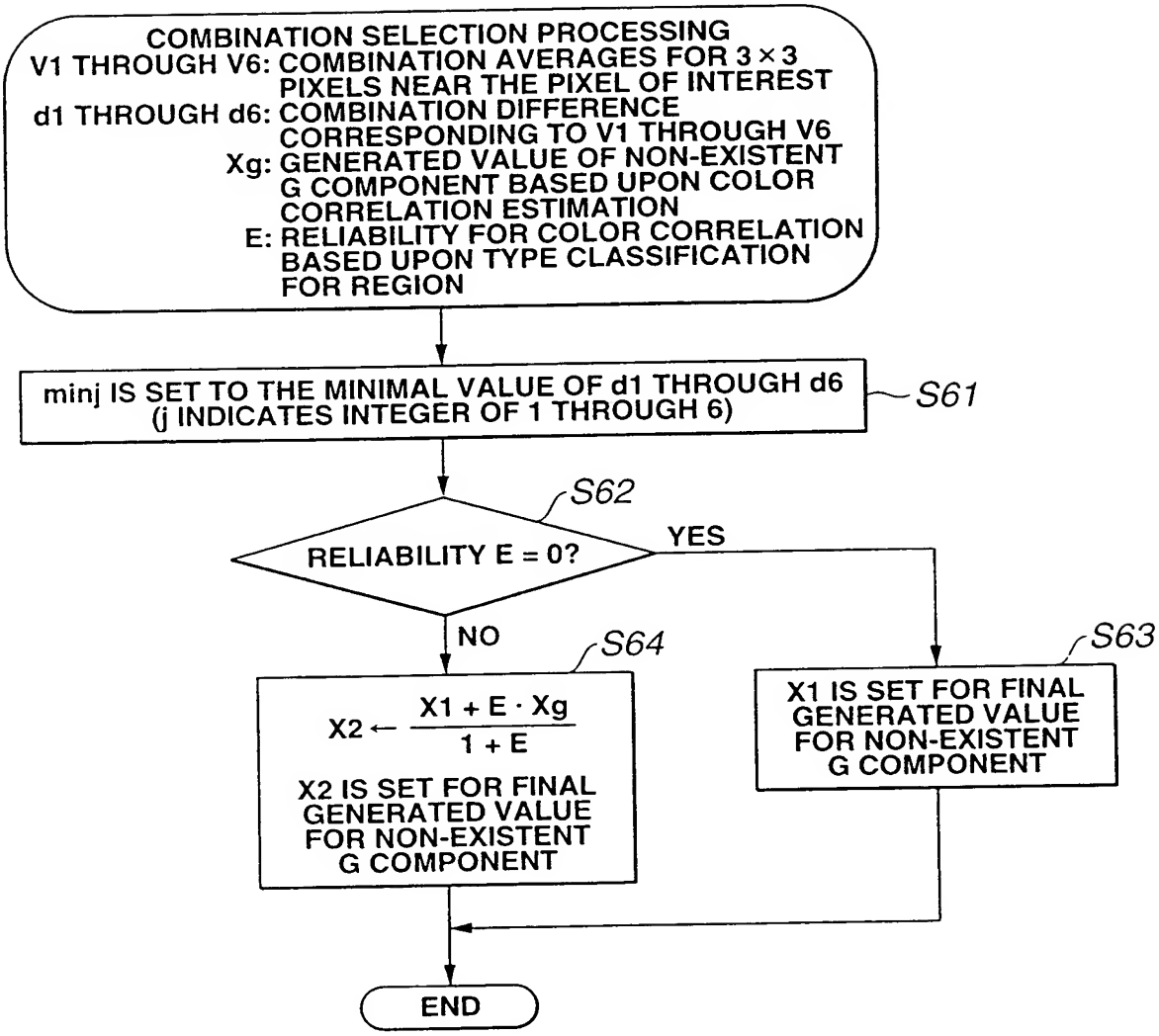

COMBINATION SELECTION PROCESSING
V1 THROUGH V6: COMBINATION AVERAGES FOR 3×3 PIXELS NEAR THE PIXEL OF INTEREST
d1 THROUGH d6: COMBINATION DIFFERENCE CORRESPONDING TO V1 THROUGH V6
Xg: GENERATED VALUE OF NON-EXISTENT G COMPONENT BASED UPON COLOR CORRELATION ESTIMATION
E: RELIABILITY FOR COLOR CORRELATION BASED UPON TYPE CLASSIFICATION FOR REGION
minj IS SET TO THE MINIMAL VALUE OF d1 THROUGH d6 (j INDICATES INTEGER OF 1 THROUGH 6)
S61
S62
RELIABILITY E = 0?
YES
NO
S64
X2 ← (X1 + E · Xg) / (1 + E)
X2 IS SET FOR FINAL GENERATED VALUE FOR NON-EXISTENT G COMPONENT
S63
X1 IS SET FOR FINAL GENERATED VALUE FOR NON-EXISTENT G COMPONENT
END

FIG.15A

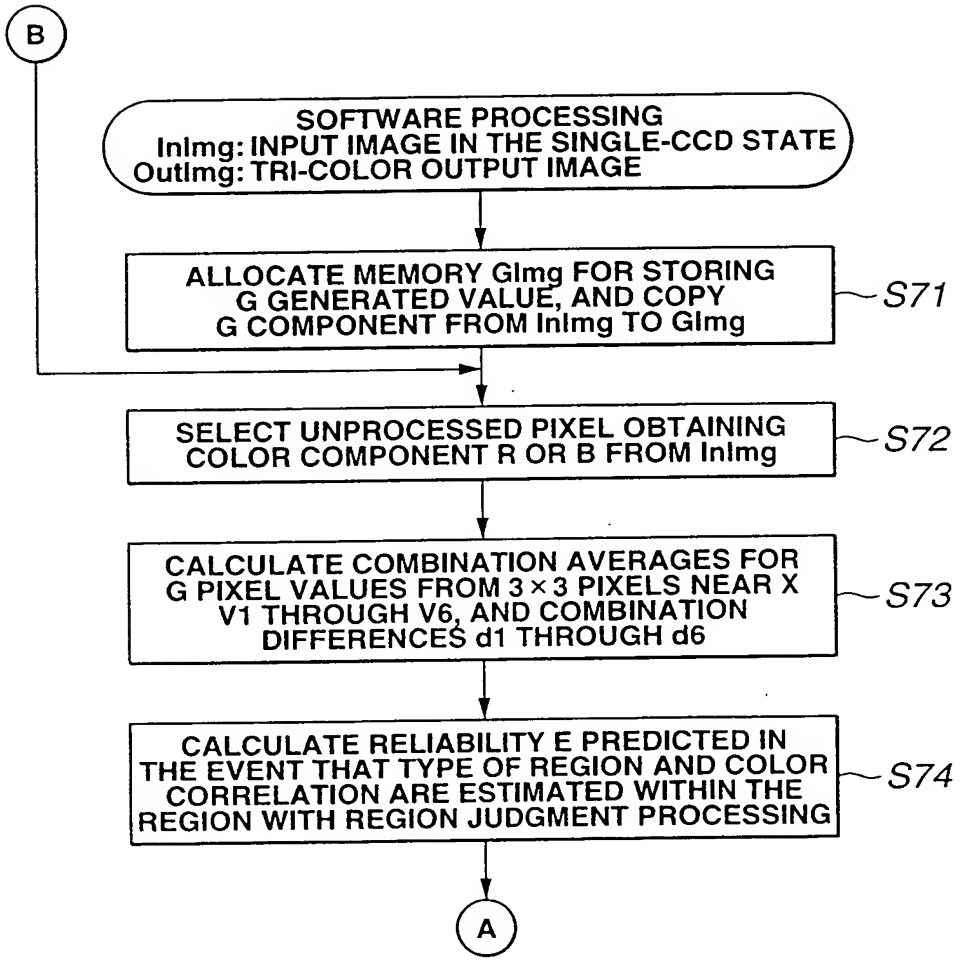

B
SOFTWARE PROCESSING
InImg: INPUT IMAGE IN THE SINGLE-CCD STATE
OutImg: TRI-COLOR OUTPUT IMAGE
ALLOCATE MEMORY GImg FOR STORING G GENERATED VALUE, AND COPY G COMPONENT FROM InImg TO GImg
S71
SELECT UNPROCESSED PIXEL OBTAINING COLOR COMPONENT R OR B FROM InImg
S72
CALCULATE COMBINATION AVERAGES FOR G PIXEL VALUES FROM 3 × 3 PIXELS NEAR X V1 THROUGH V6, AND COMBINATION DIFFERENCES d1 THROUGH d6
S73
CALCULATE RELIABILITY E PREDICTED IN THE EVENT THAT TYPE OF REGION AND COLOR CORRELATION ARE ESTIMATED WITHIN THE REGION WITH REGION JUDGMENT PROCESSING
S74
A

FIG.15B

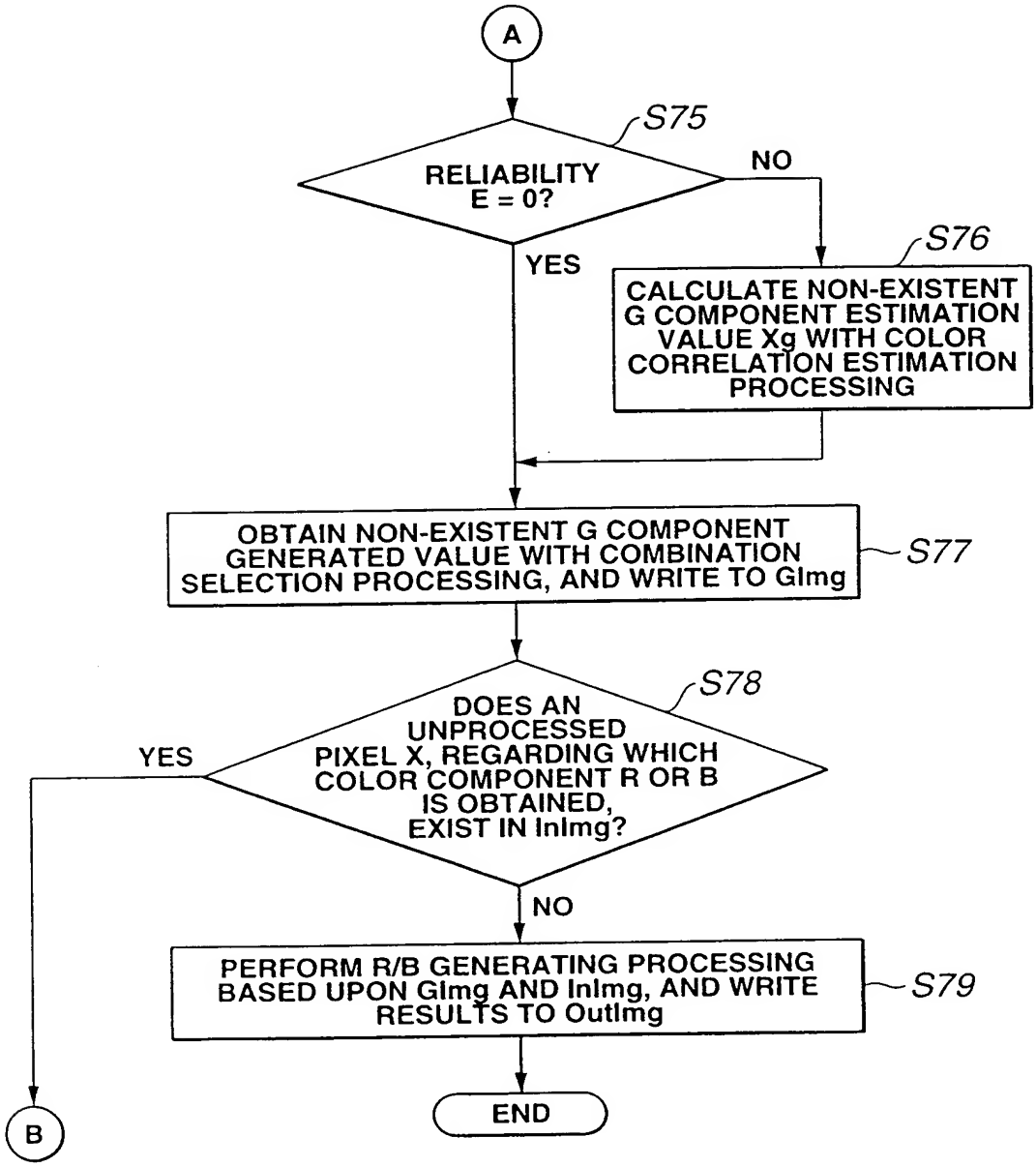

A
S75
RELIABILITY E = 0?
NO
YES
S76
CALCULATE NON-EXISTENT G COMPONENT ESTIMATION VALUE Xg WITH COLOR CORRELATION ESTIMATION PROCESSING
OBTAIN NON-EXISTENT G COMPONENT GENERATED VALUE WITH COMBINATION SELECTION PROCESSING, AND WRITE TO Glmg
S77
S78
DOES AN UNPROCESSED PIXEL X, REGARDING WHICH COLOR COMPONENT R OR B IS OBTAINED, EXIST IN Inlmg?
YES
NO
PERFORM R/B GENERATING PROCESSING BASED UPON Glmg AND Inlmg, AND WRITE RESULTS TO Outlmg
S79
END
B

FIG.16A

B	G	B	G
G	R	G	R
B	G	B	G
G	R	G	R

FIG.16B

B	G1	B
G2	R0	G3
B	G4	B

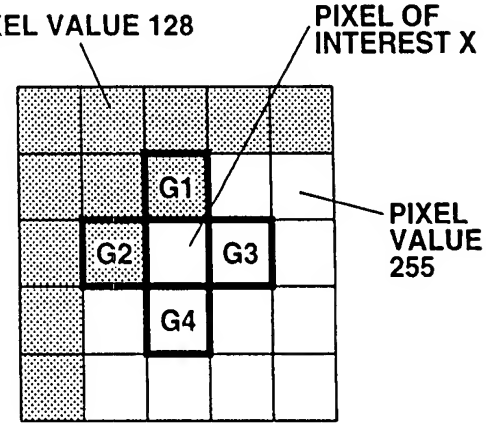
PIXEL OF INTEREST X

$$aV = \frac{G1 + G4}{2},\ dV = |G1 - G4|$$

$$aH = \frac{G2 + G3}{2},\ dH = |G2 - G3|$$

$$G0 = \begin{cases} aV \text{ (IN THE EVENT THAT } dV < dH) \\ aH \text{ (IN THE EVENT THAT } dH \leqq dV) \end{cases}$$

FIG.16C



|G1 - G4| = |G2 - G3|

FIG.17

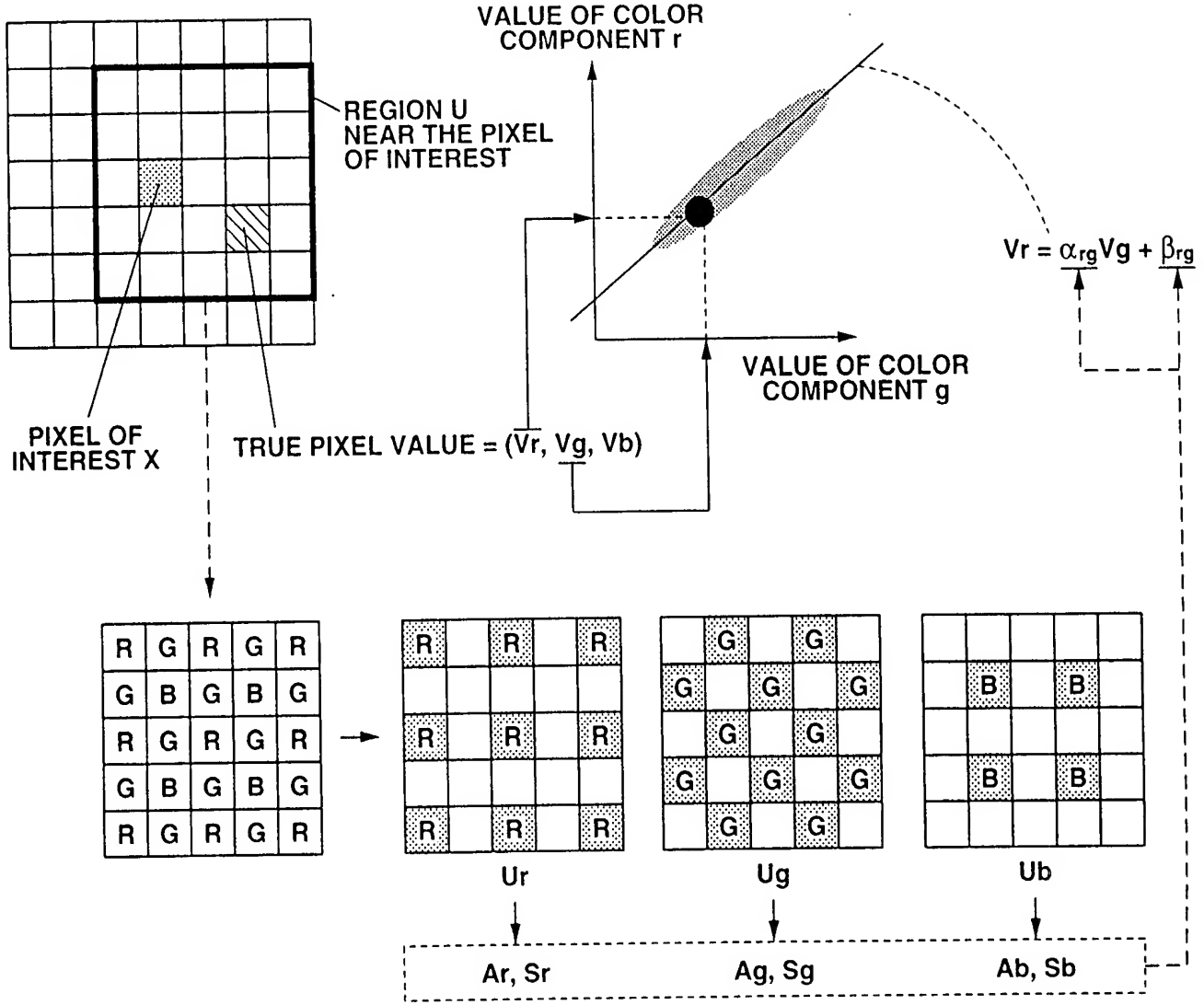

VALUE OF COLOR COMPONENT r
REGION U NEAR THE PIXEL OF INTEREST
Vr = αrgVg + βrg
VALUE OF COLOR COMPONENT g
PIXEL OF INTEREST X
TRUE PIXEL VALUE = (Vr, Vg, Vb)
R G R G R
G B G B G
R G R G R
G B G B G
R G R G R
Ur
Ug
Ub
Ar, Sr
Ag, Sg
Ab, Sb

FIG.18

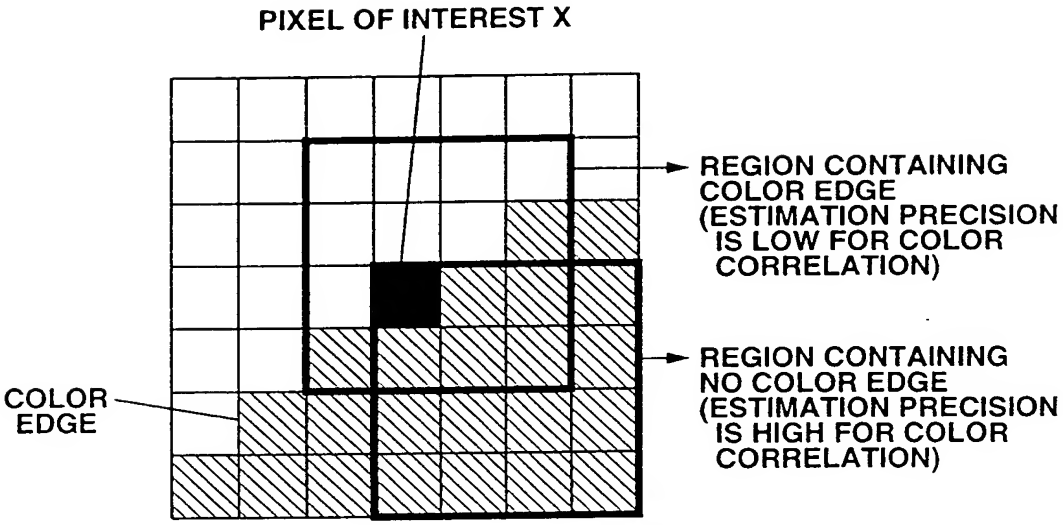
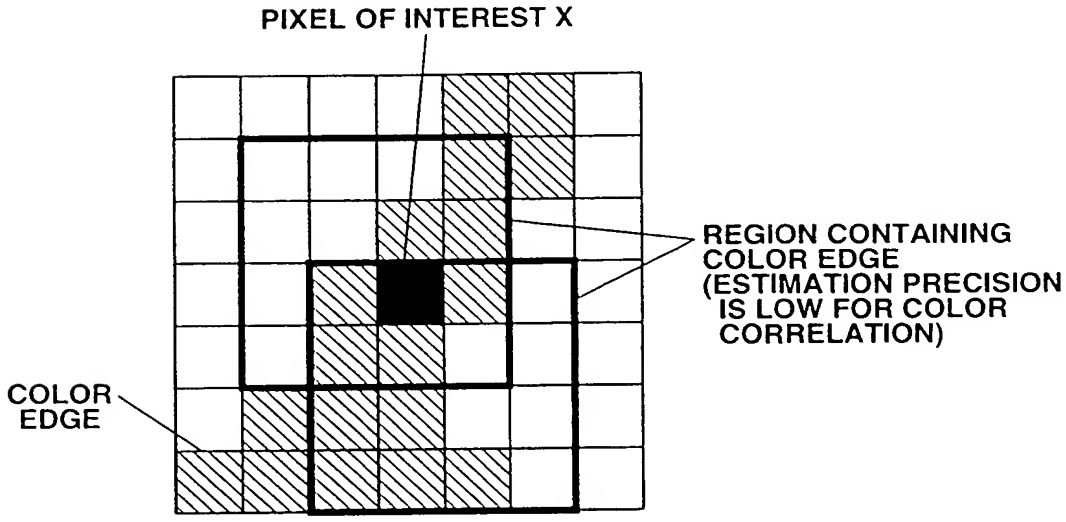

PIXEL OF INTEREST X
REGION CONTAINING COLOR EDGE (ESTIMATION PRECISION IS LOW FOR COLOR CORRELATION)
REGION CONTAINING NO COLOR EDGE (ESTIMATION PRECISION IS HIGH FOR COLOR CORRELATION)
COLOR EDGE

FIG.19


PIXEL OF INTEREST X
REGION CONTAINING COLOR EDGE (ESTIMATION PRECISION IS LOW FOR COLOR CORRELATION)
COLOR EDGE